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ADVERSE WEATHER TESTS OF THE HH-53C HELICOPTER

DONALD A. REILLY, CAPTAIN, USAF

TECHNICAL REPORT ASD-TR-70-51

DECEMBER 1970

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FOREWORD

This report was prepared by the Aerosubsystems Section, Directorate of Flight Test, Aeronautical Systems Division, Wright-Patterson AFB, Ohio. The report presents the results of the USAF Category II Adverse Weather Tests of the Sikorsky HH-53C helicopter. The flight tests were conducted by the Directorate of Flight Test, Aeronautical Systems Division, during December 1969 and January 1970 at Wright-Patterson AFB, Ohio. The project pilot was Major Frank W. Larson of the Cargo Operations Branch; the project engineer and Test Director was Captain Donald A. Reilly of the Adverse Weather Section (redesignated the Aero Subsystems Section on 1 July 1970 when the All-Weather test mission was functionally transferred to Edwards AFB, California). Other pilots assisting on this project during the flight phase were Majors Jacob F. Goble and Edward L. Heft.

The work was initiated under System No. 482A. Studies covered by this report were conducted from 19 December 1969 to 30 January 1970. The report was submitted to the Helicopter Program Division, Combat Systems Program Office, Deputy for Systems Management, on 26 August 1970 for initial review.

The report was released by the author 14 October 1970 for publication as an ASD Technical Report.

This technical report has been reviewed and is approved.

RICHARD O. RANSBOTTOM
Colonel, USAF
Director of Flight Test

ABSTRACT

Instrumentation and thermocouples were installed to record basic flight parameters and to pick up temperature variations in HH-53C helicopter for evaluation during all phases of operation in actual and simulated adverse weather. Eighteen missions were flown for a total flight time of 31 hours and 15 minutes. The HH-53C gave a safe performance in both running takeoff and hovering takeoff; and cruising flight in instrument conditions presented no undue hardships. This helicopter provides a large amount of IFR instrumentation and several approach airspeeds for instrument landing, and characteristically displayed satisfactory handling and control in instrument flight, with reasonable safety and recovery capability in case of subsystem failure. Holding patterns and turns were executed according to procedures outlined in AFM 51-37. Tentative procedures and comments by pilots were used in accomplishing instrument and missed approaches. Practice touchdowns up to 60 knots were made. Takeoffs and landings in snow helped in establishing procedures for meeting "white-outs" experienced in powdery snow. Landing sequences were designed to assist pilots in poor visibility. Uncleared runways and extreme weather conditions during the winter at WPAFB provided ideal testing conditions of ground handling and taxiing on snow and ice.

Detailed summaries of highly successful flights in natural icing conditions are described. Although an increase in overall vibration was noticed as ice built up on the control surfaces, once the vibrations reached a mild intensity, the ice on the control surfaces appeared to shed, causing the vibration to subside. In light-to-moderate turbulence during flights at low altitude no unusual problems were experienced. In addition to flight and ground handling evaluations, instrument panel, service accessories, lighting systems, heating and ventilating systems, etc. were continuously monitored. Recommendations for improvements or modifications are proposed along with new or revised procedures for operation to be included in the All-Weather Section of the Flight Manual T. O. 1H-53(H)B-1.

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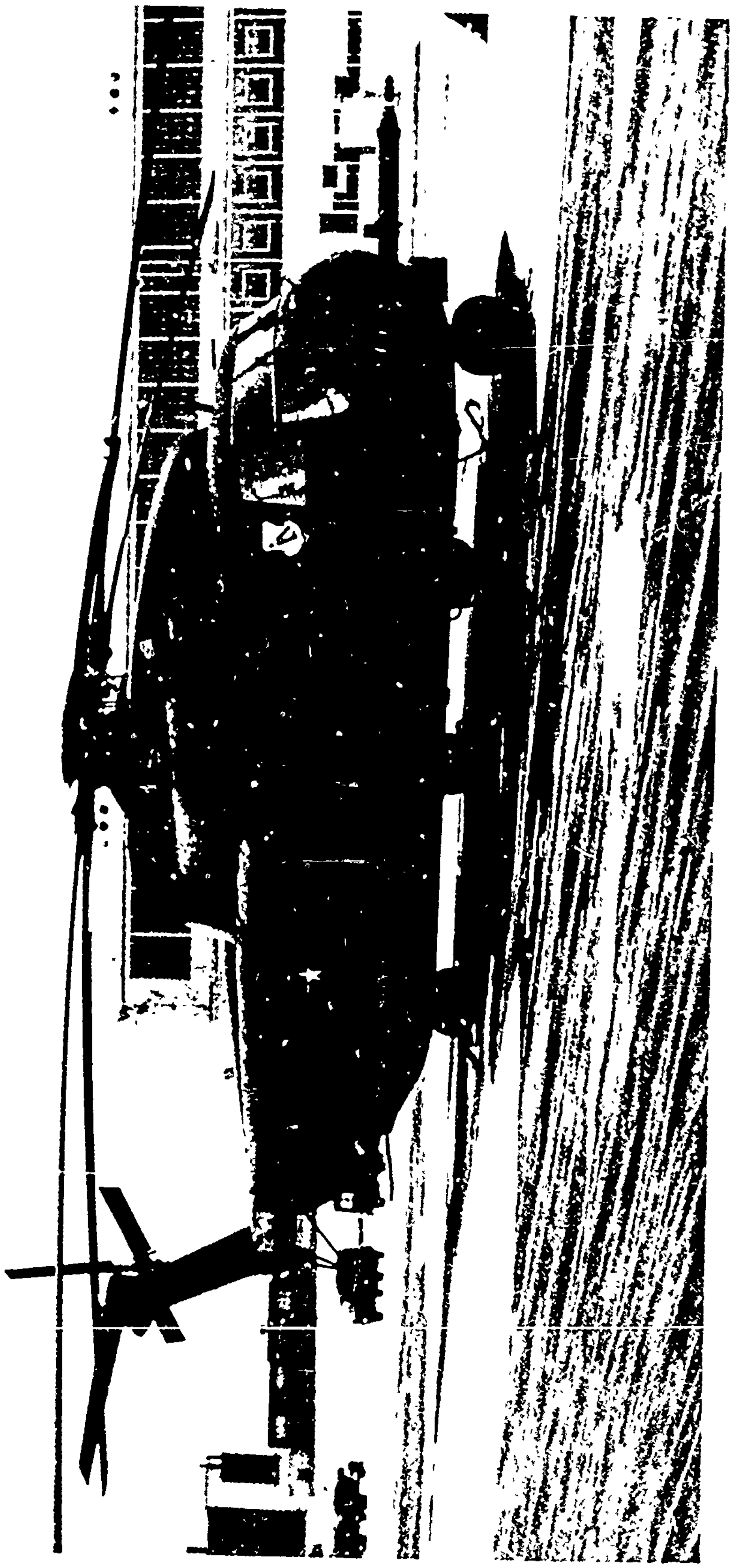
LIST OF ABBREVIATIONS

Abbreviation	Description and Dimensional Units
MSL	mean sea level (feet)
KIAS	knots indicated airspeed (knots)
LWC	liquid water content (grams/cubic meter)
VFR	visual flight rules
IFR	instrument flight rules
GCA	ground-controlled approach
OAT	outside air temperature (°C)
VOR	VHF omnidirectional range
SPO	System Program Office
ILS	instrument landing system
TACAN	tactical air navigation
AST	Directorate of Flight Test, Hq ASD
ASD	Aeronautical Systems Division
Hz	Hertz (cycles per second)
EAPS	engine air particle separator
AFCS	automatic flight control system
AGL	above ground level (feet)
BAR ALT	barometric altitude hold feature of the AFCS
NM	nautical mile
lb	pound (pound mass)
fpm	feet per minute (feet/minute)
RCR	runway condition report (arbitrary scale based on deceleration)
ECP	engineering change proposal
N_g	gas generator compressor speed
T_5	turbine inlet temperature



SECTION I

INTRODUCTION

PURPOSE OF THE TESTS

1. The purpose of the USAF Category II Adverse Weather tests was to evaluate the HH-53C helicopter and its subsystems during all phases of operation in actual and simulated adverse weather, recommend improvements to equipment and procedures, and establish All Weather operating procedures and techniques for inclusion in Section IX of the Flight Manual T.O. 1H-53(H)B-1.

TEST AIRCRAFT

2. The test aircraft, HH-53C, S/N 68-10354, was instrumented to record most of the basic flight parameters displayed on the pilot's instrument panel, and in addition, had selected temperature pickups (thermocouples) located througout the aircraft. The flight data were recorded on a photopanel located in the cargo compartment, and engine/windshield temperature data were recorded on a magnetic tape deck located next to the photopanel.

RESULTS

3. A total of 31 hours and 15 minutes were flown during eighteen missions at Wright-Patterson AFB, Ohio. The results of the Adverse Weather tests are contained in Table I and the paragraphs that follow.

SECTION II

ADVERSE WEATHER TEST MISSIONS

TABLE I

Mission No.	Date	Flight Time (Hours + Minutes)	Mission Objective
1	19 Dec 69	1+20	Tower Fly-By
2	30 Dec 69	2+05	VFR ILS Approaches
3	30 Dec 69	2+05	Hovering/Running Takeoffs
4	31 Dec 69	1+00	Takeoff/Landing on Ice
5	6 Jan 70	1+20	Airspeed/Altimeter Pace
6	6 Jan 70	2+00	Takeoff/Landing in Snow
7	7 Jan 70	2+05	Airspeed/Altimeter Pace
8	15 Jan 70	0+10 (1+00 Grd)	Contaminant Tests
9	15 Jan 70	1+35	Enroute Cruise and Nav. Check
10	15 Jan 70	2+15	Night Formation Flight
11	16 Jan 70	2+15	Takeoff/High Angle Landings
12	16 Jan 70	1+20	Natural Icing Flight
13	20 Jan 70	2+05	Natural Icing Flight
14	20 Jan 70	1+35	Night/Turbulence Flight
15	23 Jan 70	1+50	Natural Icing Flight
16	26 Jan 70	2+20	Successful Icing Flight
17	26 Jan 70	1+35	Successful Icing Flight
18	30 Jan 70	2+20	Enroute Nav. and Turbulence*
	TOTAL HOURS	31+15	

*Ferry Flight to Climatic Laboratory.

NOTE: In addition to the above listed objectives for each mission, IFR approaches (ILS, TACAN, GCA, and ADF/VOR) were flown when convenient throughout each mission.

SECTION III

INSTRUMENT FLIGHT CHARACTERISTICS

GENERAL

4. The HH-53C helicopter has satisfactory handling and control characteristics for performing instrument flight. The Automatic Flight Control System (AFCS) makes flying the HH-53C in IFR conditions as comfortable as most fixed-wing aircraft, while still providing the margin of safety required to safely recover the helicopter in the event of normal subsystem failure. The helicopter is highly versatile in adverse weather because of the large amount of IFR instrumentation available. In addition, several airspeeds can be selected that will provide safe and reliable flight during approaches to an instrument landing.

TAKEOFF AND INITIAL CLIMB

5. Two types of takeoffs can be performed safely in instrument conditions: Running takeoffs and hovering takeoffs. However, vertical or hovering takeoff, where visual reference with the ground is lost before sufficient forward speed is attained, is not recommended because of unreliable indications of airspeed and rate-of-climb. Rotor wash disrupts airflow such that indicated airspeed, rate-of-climb, and barometric altimeter readings should not be relied upon below 40 KIAS.

6. Instrument takeoffs were practiced during nearly every mission. Procedures and techniques derived from these investigations are listed in Paragraphs 46 through 55. Typical instrument takeoff profiles are shown in Figure 1.

7. Directional control of the helicopter during takeoff had to be maintained with the rudder pedal. The heading-hold feature of the AFCS would not maintain heading without assistance from the pilot during both running and hovering takeoffs.

LEVEL FLIGHT

8. Cruising flight in instrument conditions presents no undue hardships. The AFCS, along with navigational equipment and attitude instruments, make

instrument flight in the HH-53C helicopter very similar to flight in a fixed-wing aircraft. Sufficient instruments and controls are available to fly the helicopter in IFR conditions from either the pilot's or copilot's position. The various tasks of cruising flight in IFR conditions (such as aircraft control, radio monitoring, navigational fixes) may be shared by the various members of the crew so that frequent relief is possible and fatigue is kept at a minimum. Procedures for Instrument Cruise are listed in Paragraph 57.

DESCENTS

9. Normal descents were not difficult to execute in IFR conditions. Procedures for enroute and autorotational descents are listed in Paragraph 59.

HOLDING

10. Holding patterns were flown according to the procedure outlined in AFM 51-37, as well as other procedures developed for All-Weather testing. After entering the holding pattern, the helicopter was trimmed at 100 to 120 KIAS in level flight on the inbound or the outbound leg, and not retrimmed during turns. During conditions of high gross weight or high density altitude, or at the pilot's discretion, the airspeed can be reduced to the minimum single engine airspeed of 80 KIAS. A standard-rate turn (three degrees per second at approximately 10 to 15 degrees bank angle) was executed by applying cyclic side pressure, momentarily touching one of the rudder pedals to engage AFCS turn coordination, and holding cyclic pressure throughout the entire turn. In order to level out on the opposite leg of the pattern, the pilot simply neutralized the cyclic control. This procedure provided an added margin of safety should the pilot become disoriented or experience vertigo during the turn in IFR conditions, because the aircraft was always trimmed for level flight. Crosswinds were compensated for by changing heading during the straight legs to maintain desired ground track.

INSTRUMENT APPROACHES

11. GCA/ILS, TACAN, and ADF/VOR approaches were flown at several different airspeeds and descent rates in order to derive a set of IFR approach procedures for inclusion in the pilot's flight manual. Approaches were flown initially in VFR conditions, until tentative IFR procedures could be drafted

from the consensus of pilot opinion. These procedures were then verified by flight in actual adverse weather and low visibility conditions. The pilots and engineers gave consideration to the helicopter's handling characteristics, power requirements, and flight safety in formulating the procedures listed in Paragraph 60 and Figures 2 through 4.

MISSED APPROACHES

12. A missed approach can be executed at any time during the approach prior to touchdown by increasing collective pitch control to climb power and maintaining a level pitch altitude.

LANDINGS

13. Two types of IFR landings were evaluated, running or hovering. A running landing was accomplished by flaring the helicopter near the end of the final approach leg (at minimums*) to reduce airspeed sufficiently to level out and touch down at or below 60 KIAS. Procedures are listed in Paragraph 62. These procedures were carried one step further in hovering by holding the flared attitude longer and transitioning to a normal VFR hovering touchdown.

14. The nose gear was restricted to landing speeds of 40 knots or less. This limit was imposed because of the limited braking and structural integrity of the gear. However, during Adverse Weather testing, it was found that a much more comfortable landing could be accomplished, with less flare over the middle marker, by touching down on the main gear at 60 knots, and allowing the nose gear to contact the runway at or below 40 knots. The reduced flare that accompanied the higher touchdown speed allowed the pilot more forward visibility at the critical decision altitude, the point at which a missed approach would be executed if the pilot could not see the runway threshold. The extra few hundred feet of landing rollout experienced during touchdowns at 60 knots were considered minimal, and would in no way hamper landings on prepared runways. Touchdown speeds could be reduced after IFR approaches to unprepared or isolated outposts when conditions warrant.

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*Minimum altitude at which the runway should be in sight (decision height).

15. As an interim measure, the maximum touchdown speed is 40 knots as shown in the Flight Manual procedures section of this report. However, an ECP should be initiated to "beef-up" the nose gear to allow the helicopter to be landed at the more desirable IFR landing speed of 60 knots. All applicable sections of the handbook, including Section IX, should then be changed accordingly.

TAKEOFFS AND LANDING IN SNOW

16. Figure 5 depicts the typical whiteout experienced when operating the helicopter near the ground in powdery snow. This phenomenon occurs during low hovers, takeoffs, and landings.

17. As a result of the landing sequence shown in Figure 5 (Mission No. 6), the pilots and engineers adopted procedures that minimized the chances of getting completely disoriented when landing in powdery snow. It was found that when the natural horizon was totally obscured by rotor-blown snow, visibility was reduced to about 100 feet directly in front of the helicopter. Once this happened and a total whiteout was established, the pilot became dependent on objects on the ground near the intended landing zone, in addition to his attitude indicator, for visual indications of the helicopter's attitude. Taxi lights, stakes, and flares were helpful in identifying the ground during a whiteout. The only factor that prevented the pilot from aborting the landing mentioned above was his ability to distinguish small clumps of grass sticking through the snow cover directly in front of the helicopter.

NIGHT FLYING

18. Except for the minor discrepancies listed in Paragraph 63, the helicopter was found to have acceptable lighting for IFR operations at night.

SECTION IV

GROUND HANDLING CHARACTERISTICS

19. The ground handling and taxi characteristics of the helicopter were thoroughly evaluated on snow and ice-covered surfaces. On several occasions during January 1970, weather conditions at Patterson Field (WPAFB) were such that all conventional fixed-wing aircraft were grounded because of uncleared taxiways and low RCR's. Throughout most of the month, glaze ice, slush, and extremely rough ice were present on the taxiways. The rough ice was the result of vehicular traffic on snow. The snow eventually turned to slush, and then refroze with large ruts and furrows. It was in these conditions that the helicopter was operated almost continuously, and found to possess satisfactory ground handling characteristics for Adverse Weather operation.

20. Skidding was an ever-present danger on glare ice. It was determined that cyclic controls should be used as a primary braking force rather than wheel brakes. Short radius turns should be avoided whenever possible. Extreme caution was exercised when patchy ice existed on the ramp, because of the possibility of unequal tire traction in turns. When large ruts, furrows, accumulations of snow or slush existed on uncleared runways, increased "collective" (pitch control) was required to reduce the strain on the landing gear and to overcome the resistance.

21. It was found that there was very little tendency for rotor wash to "kick up" snow directly in front of the helicopter in such a manner as to obscure the windshield. During taxi operations, the airflow around the helicopter tended to throw the snow away and clear of the helicopter, with very little of it being reingested in the rotors and deposited on the fuselage. Cargo compartment windows sometimes became obscured with snow blown directly up from the ground.

22. No ground resonance was experienced during the test. There was no tendency for the engines to ingest snow or loose ice from the ramp during taxi, takeoff, or landing.

SECTION V

NATURAL ICING FLIGHTS

23. A total of five flights, two of which were highly successful, were devoted to ferreting out natural icing conditions. A brief summary of each flight follows.

24. Mission No. 12, 16 January 1970: Flight through broken cumulus clouds at 2000 to 3000 feet MSL (local terrain was 1000 feet MSL), and indicated temperatures of 0 to -5°C, proved futile. Cloud moisture contents appeared to be very low. No icing was encountered.

25. Mission No. 13, 20 January 1970: Weather was reported to be a layer of scattered clouds at 2000 feet MSL, with a higher overcast of stratus clouds and light blowing snow in the area. A very light coating of frost, barely perceptible to the eye, accumulated on the stagnation points of the fuel tank pylons and drop tanks after 45 minutes of flight through the stratus clouds at altitudes of 1500 to 9500 feet MSL and temperatures between -11 and -14°C. All moisture appeared to be frozen and precipitating out as snow. At 100 KIAS, cruise guide indications climbed from 5 to 10% and remained steady.

26. Mission No. 16, 26 January 1970: Probably one of the most fruitful flights; as far as intentionally looking for and finding ice was concerned, this mission proved a complete success. The weather was solid overcast, with a 1500-foot ceiling and reported light-to-moderate icing conditions. The temperatures were slightly below freezing (0 to -3°C), and the clouds were moisture-laden in the region between 2500 and 4000 feet MSL. The helicopter penetrated the stratus deck and immediately started to accumulate ice on all of the smaller diameter probes, such as antenna masts, windshield wipers, pitot masts, and air rescue hoist braces. Rate of ice accumulation was fairly slow, approximately 1/16 to 1/8 inch of ice per minute, but consisted of a mixture of rime and clear ice that eventually produced the mushroom buildup shown in Figure 6. Ice accreted at a slower rate on blunt objects such as sponsons, fuel tank pylons, and drop tanks, and then only in the immediate vicinity of the leading

edge. Formations of this type are typical of icing conditions where small water droplets do not have the momentum to cross the aerodynamic streamlines of blunt objects except near the stagnation point.

27. An average airspeed of 100 KIAS was maintained to simulate approach to an instrument landing. A slight increase in overall vibration was noticed periodically as ice built up on the control surfaces. A mild 1-Hz vertical vibration, a lateral shuffle, or a medium frequency "chop" was felt as cruise guide indications increased from 15 to 20%. Once the vibration reached this mild intensity (after about every 10 to 12 minutes of flight), the ice on the control surfaces appeared to shed, allowing the cruise guide to return to 15%. Vibration quickly subsided and did not return until just prior to another ice-shedding routine. During this period of time, the pilot avoided making power changes or control inputs in order to determine if the ice would shed of its own accord during undisturbed flight or if it needed prodding with random cyclic inputs. It appeared that the former was the case.

28. To retain as much of the structural ice as possible for analysis and measurement, a steep landing approach was set up at Clinton County AFB, Ohio. As the helicopter was maneuvered in a tight, descending turn, well below the freezing level (approximate temperature +5°C), chunks of ice were observed by the crew being hurled from the rotor disk area. The chunks of ice were propelled in all directions. Had these chunks of ice impacted with any part of the helicopter, structural damage could have occurred.

29. Immediately after landing, the rotors were shut down and the engines left in ground idle. It was during this time that the flight engineer noticed that a chunk of ice, which had formed on the EAPS attachment flange, and measured about 3 x 4 x 2 inches, broke off and entered the left engine inlet. Photographs were taken of the ice remaining on the rotor hub, tail rotor, APP protective fairing, etc., and are shown in Figures 6, 7, and 8. The ice was four inches thick on most of the small-diameter probes, and 2 to 3 inches thick on the blunter objects.

30. Postflight examination of the helicopter and engines upon return to Wright-Patterson AFB did not reveal any damage incurred by ice ingestion. The aircraft was preflighted for a second flight in the afternoon.

31. Mission No. 17, 26 January 1970: By the time the helicopter was readied for the afternoon mission, surface temperatures had dropped 10°C and light snow had begun to fall. Conditions had changed considerably since the morning flight, in that once the helicopter was leveled off at 400 feet altitude, the crew observed that most of the supercooled moisture had frozen and was precipitating out as snow.

32. The helicopter was flown to 9000 feet altitude in search of conditions more conducive to icing, but to no avail. Only about 1/4 inch of milky rime ice accumulated on the air-rescue hoist support brackets and other small probes during the entire flight. Two significant observations were recorded, however, which varied diametrically with those observed during the morning flight:

a. Ice accumulated on the nose gearbox fairing, while no other part of the aircraft was observed to be accreting ice (see Figure 7 inset). This occurred twice during the flight simultaneously on both engines. At no time during the morning flight did ice accumulate on any of the heated portion of the engine inlets. Ice on the gearbox formed rapidly (in about five minutes) and was estimated to be 1/2 inch thick just prior to being ingested by the engines.

b. The static discharge caution light remained "on" during most of the afternoon flight, and only very infrequently during the morning flight. This phenomenon occurred once before, during Mission No. 13, in similar weather. Static discharge was definitely not a reliable indication of icing conditions.

SECTION VI

FLIGHTS IN TURBULENCE

33. Light-to-moderate turbulence* was encountered twice during the test. On the first occasion the helicopter was being flown at low altitude (approximately 500 feet AGL) in winds of 18 knots, gusting to 25 knots, over the gently rolling hills in Southwestern Ohio.

34. Rapid staccato-like impulses were felt by the crew as the helicopter was maneuvered over the countryside. The AFCS (BAR ALT engaged) worked well ana showed no signs of improper damping, saturation, or any other characteristics which might be disconcerting during IFR flight. Approaches and touch-and-go running/hovering landings were made at Patterson Field in crosswind components of 18 to 25 knots at 60 degrees. No problems were experienced when lateral cyclic was used to correct for drift during any portion of the approach.

35. The second encounter with turbulence was on 30 January 1970, Mission No. 18, during straight-and-level cruising flight at 6000 feet MSL altitude and 125 KIAS, enroute from Wright-Patterson AFB, Ohio, to Patrick AFB, Florida. This turbulence was caused mainly by convective uplift and associated downdrafts which produced longer-period impulses. In these conditions of turbulence it was noted that the attitude-hold and altitude-hold features of the AFCS will sometimes work out of phase, producing large variations in power, and excursions in pitch. Once BAR ALT was disengaged, the helicopter settled down to flight that would be acceptable had IFR conditions prevailed.

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*Air Weather Service (AWS) Codes 1 through 3: Light moderate turbulence in clear air, frequent.

SECTION VII

GENERAL EVALUATION OF THE HELICOPTER AND ACCESSORIES FOR APPLICATION TO ALL-WEATHER FLYING

36. Along with the instrument flight procedures derived during this test, the pilots and engineers evaluated the helicopter's avionics, service accessories, and cockpit/cargo compartment layout for application to All-Weather flying.

COCKPIT LAYOUT

37. The cockpit was continuously evaluated throughout the test. It was found to be satisfactory for both day and night instrument flight with only minor inconveniences. The following comments and/or Unsatisfactory Reports were submitted in regard to the cockpit area:

a. Unsatisfactory Report No. ASD-R70-102: The flight engineer's station, located in the cockpit doorway, lacks a day/night utility light (P/N MS-17245-1). Suggest this light be incorporated in all aircraft to aid in reading the checklist, Tech Orders, etc.

b. The FM radio set, located on the lower center console, lacks provision for a red night light.

c. Unsatisfactory Report No. ASD-R70-105: The upper right-hand and lower center windshield blistered when anti-icing heat was applied during flight in icing conditions. Handbook procedures were adhered to prior to and during the time the panel blistered. Postflight examination did not reveal any discrepancies in the electrical system. The SPO indicated that this problem had occurred before, and a solution is being investigated under WRAMA supervision.

d. The attitude, heading, altitude, and speed display instruments located on the pilot's and copilot's instrument panel were found completely adequate to perform a safe takeoff, approach, and landing in minimum instrument conditions from either the right or left seat.

e. The radio and navigation equipment, located on the center console and instrument panel, were found to be satisfactory for all-weather flying. Sufficient navigational equipment was available to safely execute a VOR, ILS, GCA, or TACAN approach as shown in Figures 2, 3, and 4.

f. Visibility from the cockpit was found to be satisfactory for all flight and ground taxi requirements, both during the daylight hours and at night. Reflections from instrument panel lights as well as the landing and cargo lights have been kept to a minimum and present no problem. During hovering operations, the flight engineer may provide occasional directional assistance from the doorway, using the rescue winch light where required. There were no apparent distortions caused by the windshield, side windows, or the lower cockpit windows.

LIGHTING SYSTEMS

38. The various lighting systems were evaluated during two dusk/night missions. Except for the minor complaint mentioned in Paragraph 37, the helicopter's lights were rated satisfactory for night/instrument flight. The pilots exalted both the electro-luminescent formation lights and the independently controllable spotlights as particularly useful, and rated each as excellent. The formation lights greatly enhanced the wingman's depth perception at night, while proportionately reducing the visual illusion of apparent movement normally caused by a point source of light. The pilots preferred to set the rotor tip lights at full bright, the anti-collision light off, and the electro-luminescent lights to position 4 or 5 during night formation flights. The independently controllable spotlights provided more flexibility during takeoff and landing when compared with lights on the CH-3C helicopter (only one controllable light). Both the pilot and copilot were able to illuminate different areas of the landing zone.

HEATING AND VENTILATION SYSTEMS

39. Unseasonably low temperatures and high winds were recorded at Wright-Patterson AFB during the month of January 1970. Several cold soaks, ground runs, and flights were conducted in subfreezing temperatures that dipped as low as -20°C on the ground with wind-chill factors of -50°C. The heating and ventilating system was able to cope with these conditions, and after only a brief warmup period, produced a comfortable atmosphere in the cockpit and cargo compartment during ground and flight operations. A faulty cockpit thermostat was the only difficulty encountered with the heating system during a test.

40. Contaminate tests were conducted using a "sniff tester" capable of detecting 0.001% (by weight) carbon monoxide. Readings were taken in the cockpit and cargo compartment, with the door/ramp both open and closed and the heater both operating and not operating. The readings were taken while the helicopter was on the ground with the rotors turning, and in a low hover. The flight test engineer took 20 readings, each one of which showed the CO contamination level to be below the detectable range of the sniff tester. The day the tests were conducted, the wind was calm, so that no crosswind data were obtained.

WINDSHIELD WIPER SYSTEM

41. The windshield wipers were not evaluated because no rainshowers of any significance were encountered during the test.

SECTION VIII

CONCLUSIONS

42. The HH-53C helicopter has been provided with the necessary instruments, radios, and navigation equipment to accomplish missions from prepared or unprepared surfaces, under instrument flight conditions during the day or night. Flight through icing conditions is permitted within the limitations set forth in the recommended instrument flight procedures section of this report.

SECTION IX

RECOMMENDATIONS AND SPO COMMENTS

43. On the basis of the Adverse Weather Tests of the HH-53C helicopter conducted by the Directorate of Flight Test, the following recommendations are submitted to the HH-53C Helicopter System Program Office, Deputy for Systems Management, Aeronautical Systems Division, for adoption. The recommendation is stated on the left side of the page and comments with respect to the recommendation are given in the column on the right side of the page.

RECOMMENDATION	SYSTEM PROGRAM OFFICE (SPO) COMMENT
a. The All-Weather Operating Instructions documented in this report be incorporated in the pilot's flight manual, T.O. 1H-53(H)B-1.	a. Concur in concept; content is subject to engineering evaluation and wording is subject to command concurrence.
b. The necessary modifications be performed to the landing gear to increase the allowable speed from 40 to 60 knots (see Para 14, 15, and 62).	b. SPO agrees to investigate possibility of adoption. Cost and weight penalty needs to be determined.
c. An engineering analysis be conducted on the nose gearbox fairing anti-icing circuit to determine a means of preventing minor ice formation similar to that reported on Mission 12 (see Para 32a).	c. Concur.
d. The AFCS barometric altitude hold function be modified to eliminate the divergent excursions in pitch experience in convective turbulence (see Para 35).	d. Concurrence withheld. SPO agrees to investigate possibility of correcting undesirable characteristics.
e. A day/night utility light be installed at the flight engineer's station (see Para 37a).	e. Concur on desirability. Justification for ECP must include "safety" or "mission essential" certification.

RECOMMENDATIONS (CONTD)	SYSTEM PROGRAM OFFICE (SPO) COMMENT (CONTD)
f. A red night light be added to the FM radio set (see Para 37b).	f. Concur on desirability. Justification for ECP must include "safety" or "mission essential" certification.
g. The helicopter be cleared for flight in light-to-moderate icing conditions according to the provisions listed in Para 70 and 71.	g. Concur.

APPENDIX

RECOMMENDED INSTRUMENT FLIGHT PROCEDURES FOR INCLUSION IN THE ALL-WEATHER SECTION OF THE PILOT'S MANUAL

44. The instructions and procedures that follow are recommended for inclusion in the All-Weather Section of T.O. 1H-53(H)B-1. Except for some repetition which is necessary for continuity of thought, the instrument flight procedures contain only the procedures that differ, or are in addition to, normal procedures covered in other sections of the flight manual.

NOTE: THESE PROCEDURES APPLY TO THE HH-53C MODEL HELICOPTER ONLY; NOT THE HH-53B MODEL HELICOPTER. THE FLIGHT MANUAL SHOULD BE ANNOTATED WHERE THE PROCEDURES DO NOT AGREE WITH, OR ARE TOO RESTRICTIVE TO, THE CAPABILITIES OF THE HH-53B HELICOPTER.

INSTRUMENT FLIGHT PROCEDURES

PREPARATION FOR INSTRUMENT FLIGHT

45. Complete the normal inspection outlined in Section II of the flight manual. Particular attention should be given to checking the anti-icing system, pitot heat, windshield wipers, lighting, instrument systems, and navigational aids for proper operation.

WARNING: In cold weather, make sure that all instrument and flight controls have warmed up sufficiently to ensure normal operation. Check for sluggish instruments during taxiing.

INSTRUMENT TAKEOFF

46. In addition to those conditions which normally require an instrument takeoff (e.g., precipitation, fog, low ceilings, and night takeoffs), helicopter-induced restrictions to visibility, such as dust or snow blown by the rotor downwash may require an instrument takeoff. The two recommended instrument takeoff techniques are the normal (from ground or hover) and running

takeoff. The normal takeoff is not recommended when visual contact with the ground will be lost prior to attaining approximately 40 KIAS.

CAUTION: Rotor wash disrupts airflow such that indicated airspeed, rate of climb, and barometric altimeter readings should not be relied upon below 40 KIAS.

CAUTION: Turns should not normally be accomplished before attaining 80 KIAS and a 200-foot clearance above the terrain. The angle of bank under instrument conditions should not exceed 30 degrees. A standard rate turn will be approximated by a 20-degree angle of bank at 120 KIAS.

47. NORMAL INSTRUMENT TAKEOFF: (From the ground or from a hover) Adjust the attitude indicator so that the miniature aircraft is level with the horizon and cross-check the heading indicator.

48. Smoothly increase collective to takeoff power, maintaining heading and level attitude by reference to the attitude indicator and aircraft heading. This type of takeoff will require slightly more forward cyclic than is normally required for a takeoff to a hover. Maintaining a level attitude, instead of a nose-up hovering attitude, will ensure that the aircraft does not drift rearward if wind is present, and will decrease the time required to attain translational lift.

49. When a positive indication of climb has been noted on the barometric and electronic altimeters, the nose may be lowered to 5° nose-down to expedite the climb-out.

50. Upon reaching 80 KIAS, raise the nose to the horizon line on the attitude indicator, and adjust power for climb.

51. Continue instrument climb utilizing the appropriate climb speed from the performance charts.

WARNING: The pilot cannot definitely ascertain his direction of motion at very slow speeds under instrument conditions. If disoriented, maintain climb power and a level attitude using the attitude indicator. The aircraft will slowly accelerate to 80 KIAS without lowering the nose.

52. RUNNING INSTRUMENT TAKEOFF: This takeoff may be utilized when a suitable runway or cleared area is available. Align the aircraft with the takeoff direction and cross-check the heading indicator. Adjust the attitude indicator so that the miniature aircraft is level with the horizon line.

53. Begin the takeoff roll, accelerating to 40 or 50 KIAS, utilizing 30 to 40% torque.

54. When the desired airspeed is attained, first move the cyclic aft to just forward of neutral, then smoothly increase collective to takeoff power. Maintain a level attitude (pitch and bank) throughout the takeoff, by reference to the attitude indicator.

55. When 80 KIAS is attained, adjust the collective for climb power, then maintain the appropriate climb airspeed.

INSTRUMENT CLIMB

56. Instrument climb may be performed with relative ease and precision. Use maximum continuous power and climb schedule airspeeds for instrument climbs under normal conditions. The AFCS will assist in maintaining the desired altitude and heading.

INSTRUMENT CRUISE

57. The recommended airspeed from the cruise performance charts at the end of this appendix should be used for enroute cruise, unless incipient blade stall or other circumstances dictate a lower airspeed. The recommended cruise airspeed will yield the best specific fuel consumption (NM/lb) under no-wind conditions. The attitude, heading, and barometric hold features of the AFCS make instrument cruise extremely easy in smooth air. The coordinated turn feature of the AFCS will be inoperative below 60 KIAS. Cruising turns should be limited to a bank angle of 30 degrees. The BAR ALT will effectively maintain altitude if strong updrafts and downdrafts are not encountered. Slightly increased fuel consumption will result from continuous use of BAR ALT.

NOTE: In certain conditions of turbulence, particularly that associated with updrafts and downdrafts, the altitude hold features of the AFCS will sometimes work out of phase, producing large variations in power excursions in pitch. If this condition is encountered, disengage BAR ALT.

NOTE: To minimize erratic performance of BAR ALT feature due to moisture in the pitot static system, use pitot heat when flying in visible moisture with BAR ALT engaged.

HOLDING

58. Normal holding airspeed is 100 to 120 KIAS. Airspeeds may vary as conditions warrant. Normally the helicopter should be trimmed to the holding airspeed on the inbound or outbound leg of the holding pattern and not retrimmed during turns. Minimum holding airspeed is 80 KIAS.

DESCENTS

59. Enroute descents should normally be made at cruising airspeeds. Descents as part of an instrument approach should be made between 100 and 120 KIAS. Emergency descents in autorotation should be made between 80 KIAS and 100 KIAS.

CAUTION: Initiate recovery 1000 feet or more above the desired altitude when leveling off from an autorotative descent.

INSTRUMENT APPROACHES

60. During transition from descent to the appropriate instrument approach pattern, an airspeed between 100 KIAS and 120 KIAS should be adopted and maintained, until in the final turn, at which time 100 KIAS should be maintained until the airfield is sighted or a missed approach is executed. Conditions of high gross weight or high-density altitude may require a lower airspeed on "final." However, a safe single engine speed of 80 KIAS should be maintained during the entire approach. The gear should be lowered prior to starting the final descent at the glide path, approach gate, or low station. Climbs and descents in the instrument pattern are normally accomplished by making a power change, while also keeping the pitch attitude fixed. Normally a 7 to 8% torque increment will yield a 500 fpm change to the vertical speed. When this technique is used, airspeed will not change more than 10 KIAS during the climb or descent. Refer to Figures 2, 3, and 4 for typical instrument approach patterns.

MISSED APPROACH

61. A missed approach is executed by increasing collective to climb power while maintaining a level-pitch attitude. Perform the after-takeoff checklist and execute the appropriate missed-approach procedure. The radar altimeter may be used as a cross reference for determining decision altitude when executing a missed approach.

NOTE: A slight decrease in indicated airspeed and an increase in indicated altitude, without corresponding changes in aircraft position, should be expected when adding power for the missed approach. These indications are caused by the sudden change in airflow around the pitot probes and are misleading if not anticipated. Refer to the altitude and airspeed calibration charts in the appendix of the flight manual.

LANDING

62. If the field is in sight by the time minimums are reached, decelerate the aircraft by simultaneously lowering collective and raising the nose slightly in a modified flare. A running landing, or landing from a hover, may be accomplished within the normal touchdown zone after initiating a flare as low as 100 feet altitude at speeds up to 60 KIAS.

NIGHT FLYING

63. Night flying does not present any additional instrument flight problems, but does add to the physical problems associated with illumination of cockpit instrument lights and reflections from interior and exterior lights. Exterior lights may reflect off surrounding clouds and prove distracting or hamper vision.

TAKEOFF AND LANDING AT NIGHT

64. There is basically little difference in takeoff and landing techniques used during night operation as compared to those used during daytime operation. However, the pilot should be aware of a degradation in depth perception resulting from decreased lighting between the hours of early dusk and dawn. Ability to discern closure rates becomes more difficult, and extra caution should be exercised when operating in close proximity to the ground.

65. The controllable spotlights should be used to illuminate the ground during takeoffs and landings, but their use should be at the discretion of the pilot since he can best judge local conditions.

ICE, SNOW, AND RAIN

66. Check aircraft carefully for ice and snow accumulations. Engine intake areas, rotor head, blades, tail rotor, pitot tubes, APP, and heater ducts, and also shock struts should be checked for ice and snow deposits that might hamper their operation. Engine and aircraft preheats are not required for temperatures above 1°F. It is normal for engine and flight controls to initially be very stiff, but they will rapidly loosen up after the APP is started. The aircraft heater may be used to warm the inside of the aircraft after the APP has been started, and the LOW heat position will rapidly clear off any accumulations of frost or ice inside the aircraft.

WARNING: Do not engage the rotors until the flight controls are operating normally.

CAUTION: Remove all accumulations of ice and snow prior to flight. Do not chip off ice. Use de-icing fluid or pre-heat to remove accumulations of ice and snow.

CAUTION: Avoid excessive use of the windshield anti-ice on the ground to prevent cracking of the windshield.

CAUTION: Extreme care should be utilized when engaging or stopping the rotors on ice or snow. Accelerate or decelerate the rotor slowly, monitoring aircraft heading with the rotor pedals.

TAXIING

67. ICE: Use extreme caution taxiing on ice. Use cyclic control as the primary braking force, and to prevent skidding in turns. Avoid, whenever possible, short radius turns on ice, even at slow speeds, because of the danger of skidding. Do not use excessive collective on ice, as it will increase the possibility of skidding.

68. SNOW, SLUSH: Increased collective will be required to overcome the resistance of snow or slush. Taxi slowly to reduce the strain on the landing gear, and avoid mounds or furrows of snow.

TAKEOFF

69. Ensure that wheels are not frozen to the ground before attempting to take off. A slight yawing motion, induced by light tail pedal motion, should break the wheels free when they are frozen to the surface. Apply engine, windshield, and pitot heat before starting takeoff if the ground is covered with loose, powdery snow, or icing conditions exist at or near the surface. Loose snow on the ramp may be cleared from the immediate takeoff area by slowly applying collective until the aircraft is light on the struts and the rotor wash is sufficient to blow the snow clear of the aircraft. An area large enough to safely hover or takeoff can be cleared with ease using this technique.

NOTE: After takeoff, the landing gear should be re-cycled to clear the gear wells of snow or slush that may later freeze and prevent gear extension.

ICING

70. Flight in light-to-moderate icing conditions is permissible if excessive sustained vibrations are not encountered. However, flight in icing conditions should be avoided whenever possible. A slight increase in overall vibration will be noticed after entering icing conditions. This vibration may take the form of a mild 1-to-1 vertical, a lateral shuffle, or a medium frequency "chop." Normally the rotor blades will shed the ice, allowing the vibration level to build slightly, then dissipate, then start again. Cruise guide indications will rise about 5% at the peak. Ice accumulations on the rotor head will not affect the flight controls as long as the pilot cycles the controls occasionally to keep the servos clear.

71. Icing is most prevalent in areas of visible moisture and ambient temperatures of 1 to -15°C. However, engine inlet icing may occur in temperatures up to +5°C due to the cooling effect associated with reduced pressures in the engine inlet. Engine, pitot, and windshield anti-icing should be operated continuously whenever icing is expected or flight through visible moisture produces the telltale loss of Ng and rise in T_5 that are indicative of engine icing. Visual clues

of aircraft icing include the accumulation of clear or milky-white ice formation, first on thin probes such as the windshield wipers or antenna masts. followed by buildups on the stagnation points of blunter objects, such as the sponsons, fuel tank pylons, and the windshield. The windshield will normally remain clear of ice on low heat. Properly operating the engine anti-ice will keep the engine intake clear of ice, but some ice will adhere to the fairing around the oil cooler and EAPS attachment lip around the intake. The pilot should be aware of the fact that some of this ice may be ingested when the helicopter approaches a hover and airflow becomes more turbulent. The increased vibration experienced approaching a hover also helps to dislodge structural ice. Ingested ice from the EAPS attachment lip will probably be of no consequence.

WARNING: Engine inlet duct anti-icing is inoperative when EAPS is operating.

NOTE: If excessive ice accumulates on the aircraft causing vibration to exceed safe limits, change altitude or course and depart the icing conditions immediately. If this is not possible, and a landing is practical, land and wait for conditions to improve.

LANDING IN SNOW

72. Land from a hover if landing on ice-covered snow. If landing in loose, powdery snow, plan to land without a hover. Expect a whiteout if the rotor wash catches up to the aircraft before touchdown.

NOTE: If a whiteout is encountered before landing, execute a go-around by maintaining a level pitch attitude while increasing collective to takeoff power.

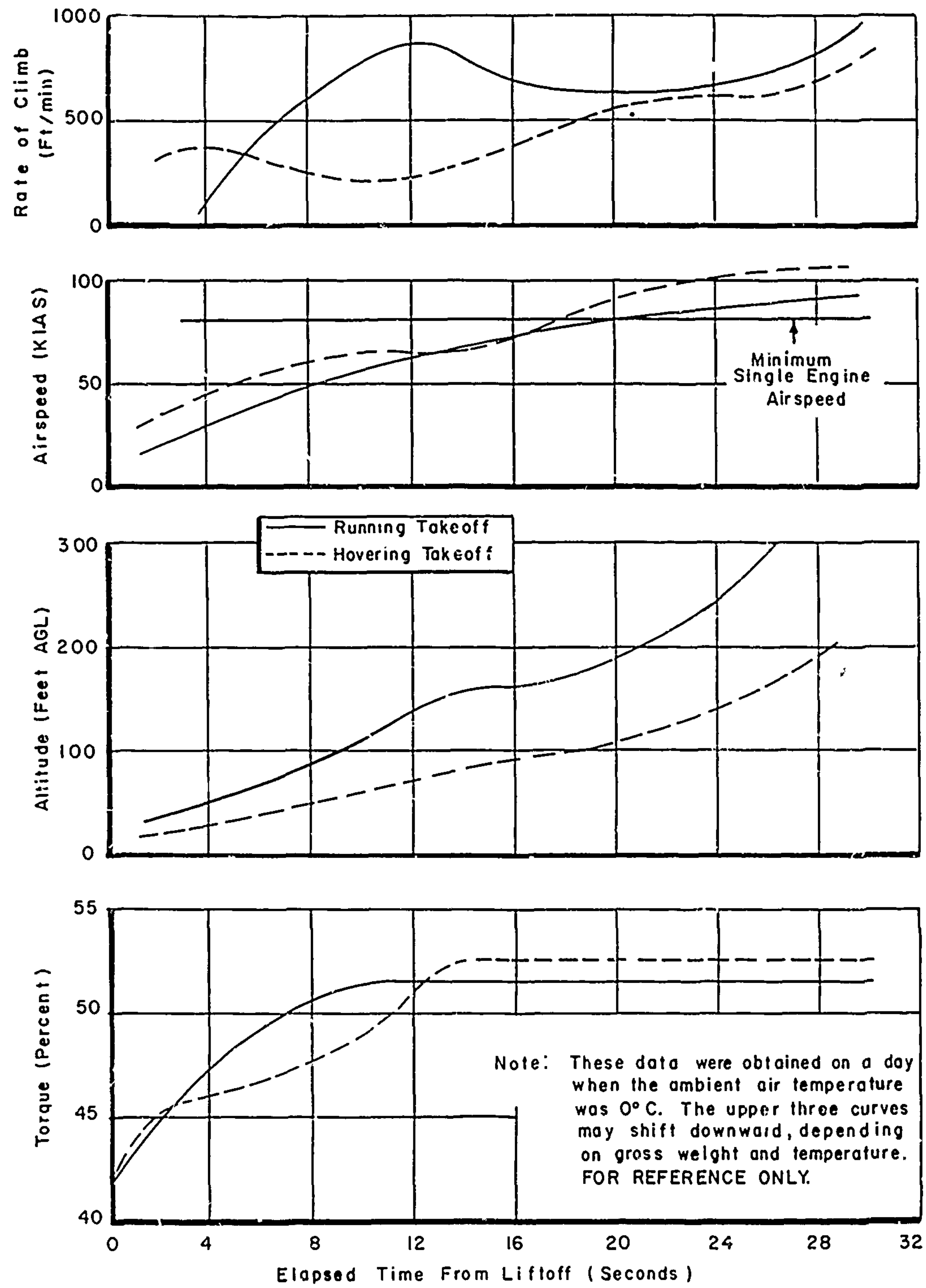
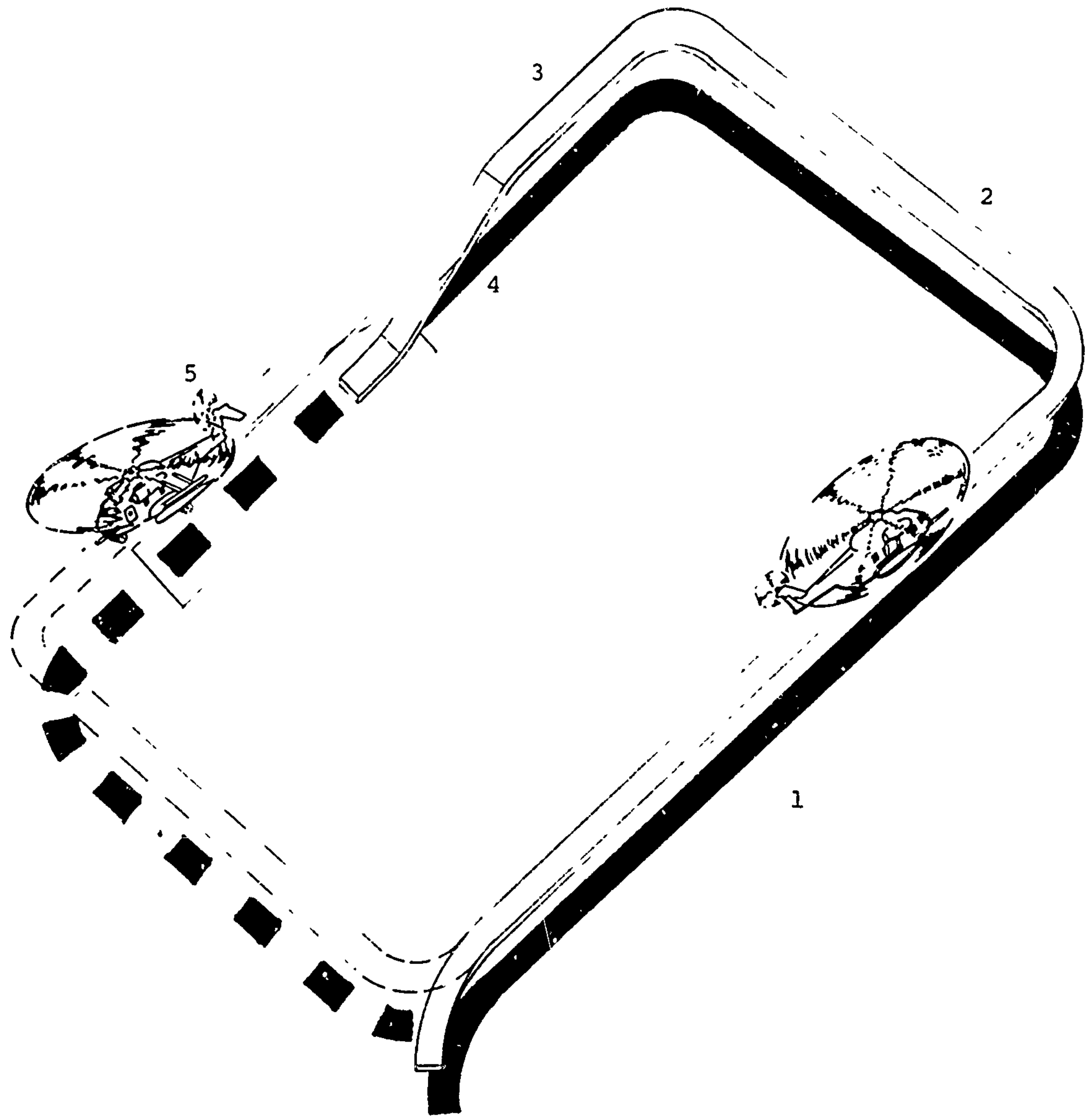


Figure 1. Typical Instrument Takeoff Time History



1 DOWNWIND LEG: Descent check complete; reduce airspeed from cruise airspeed.

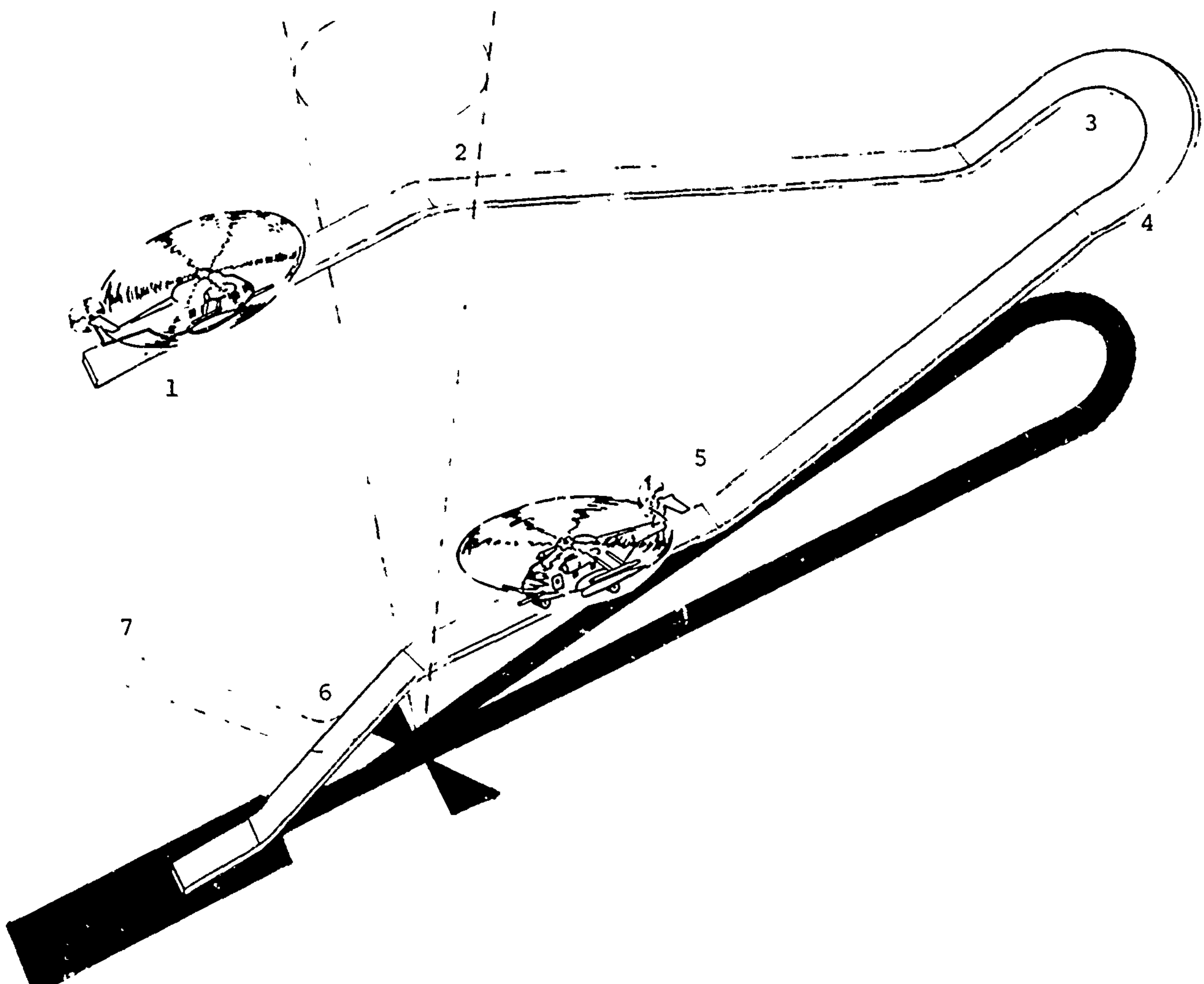
2 BASE LEG: Airspeed 120 KIAS to 100 KIAS.

3 FINAL: Before landing check complete, gear down, airspeed 100 KIAS.

4 GLIDE PATH: Maintain 100 KIAS, rate of descent as required.

5 MISSED APPROACH: Maintain 100 KIAS; increase collective to climb power. Perform after-takeoff check.

Figure 2. Ground-Controlled Approach



1 HOLDING PATTERN OR INITIAL APPROACH LEG: Descent check complete; reduce airspeed from cruise airspeed.

2 OUTBOUND DESCENT: Maintain 120 KIAS to 100 KIAS.

3 PROCEDURE TURN

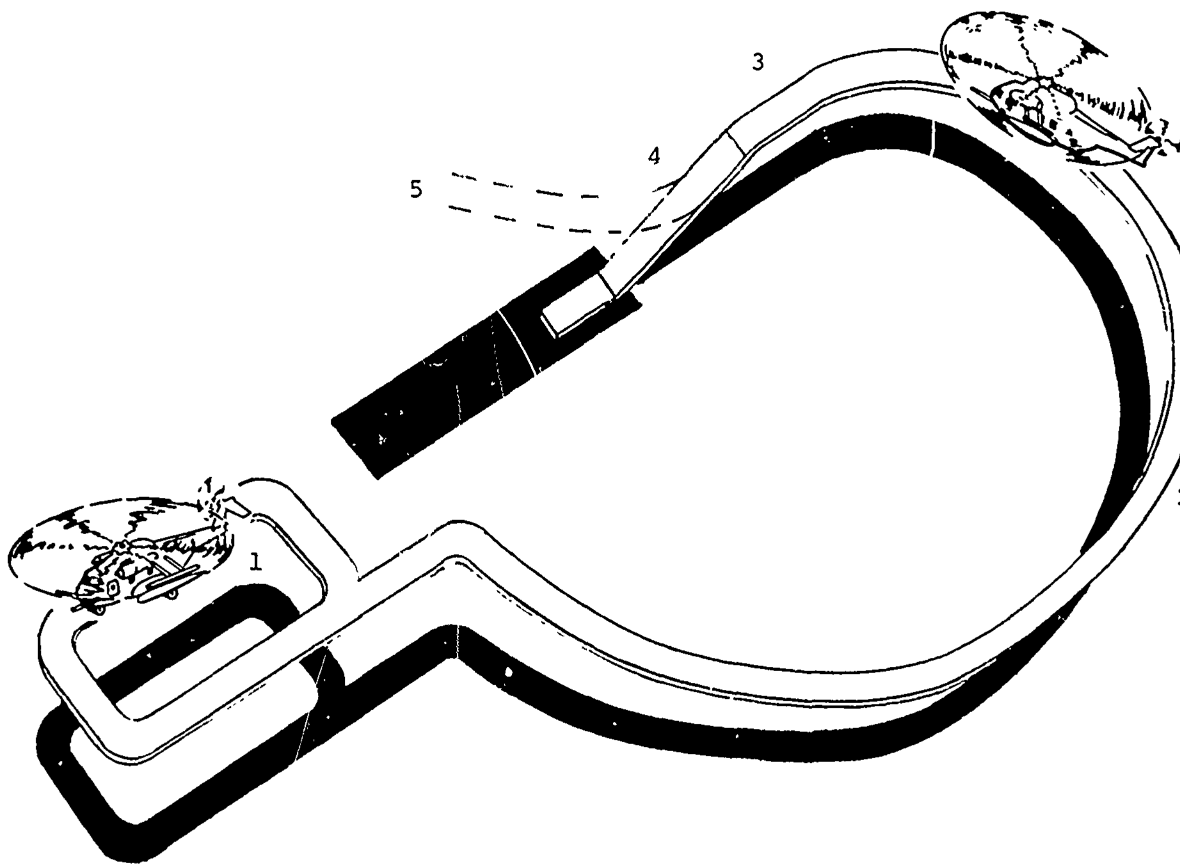
4 INBOUND DESCENT: Before landing check complete, gear down; decrease airspeed to 100 KIAS.

5 FINAL APPROACH: Maintain 100 KIAS.

6 DESCENT: Maintain 100 KIAS, rate of descent as required (approximately 500 FPM).

7 MISSED APPROACH: Maintain 100 KIAS, increase collective to climb power, accomplish after-takeoff check.

Figure 3. ADF or VOR Approach (Typical)



1 HOLDING PATTERN: Before descent check complete, airspeed 120 KIAS to 100 KIAS.

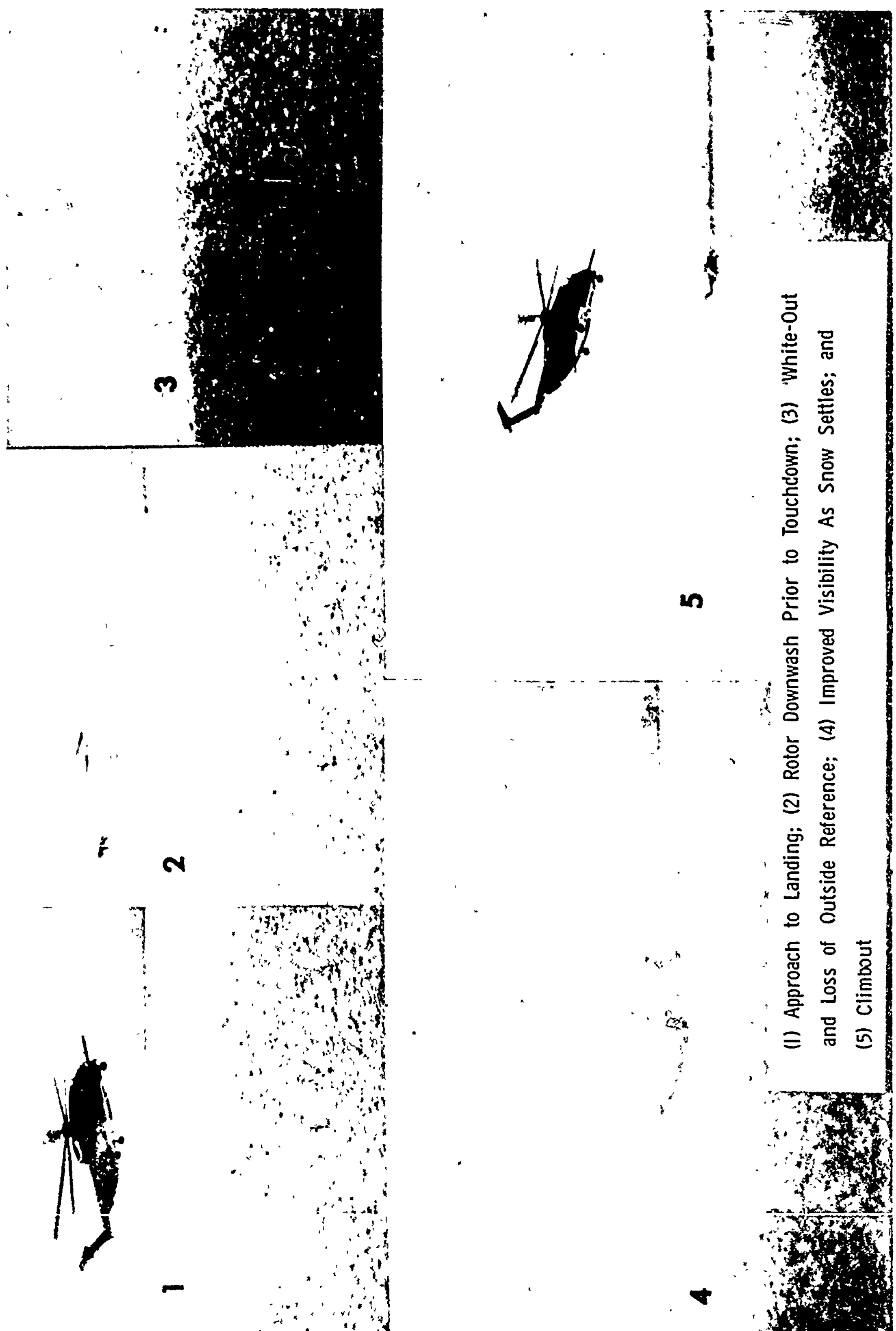
2 DME ARC: Maintain 120 KIAS to 100 KIAS, gear down.

3 GATE: Before landing check complete; reduce airspeed to 100 KIAS.

4 DESCENT: Maintain 100 KIAS, rate of descent as required (approximately 500 FPM).

5 MISSED APPROACH: Maintain 100 KIAS; increase collective to climb power, accomplish takeoff check.

Figure 4. TACAN Approach (Typical)



(1) Approach to Landing; (2) Rotor Downwash Prior to Touchdown; (3) 'White-Out and Loss of Outside Reference; (4) Improved Visibility As Snow Settles; and (5) Climbout

Figure 5. Typical "Whiteout" Experienced When Landing in Powdery Snow

Sponson and fuel tank pylon after 30 minutes in icing conditions (insert shows flight test engineer holding a 4-inch thick ice deposit from the antenna mast).

Figure 6. Sponson Icing

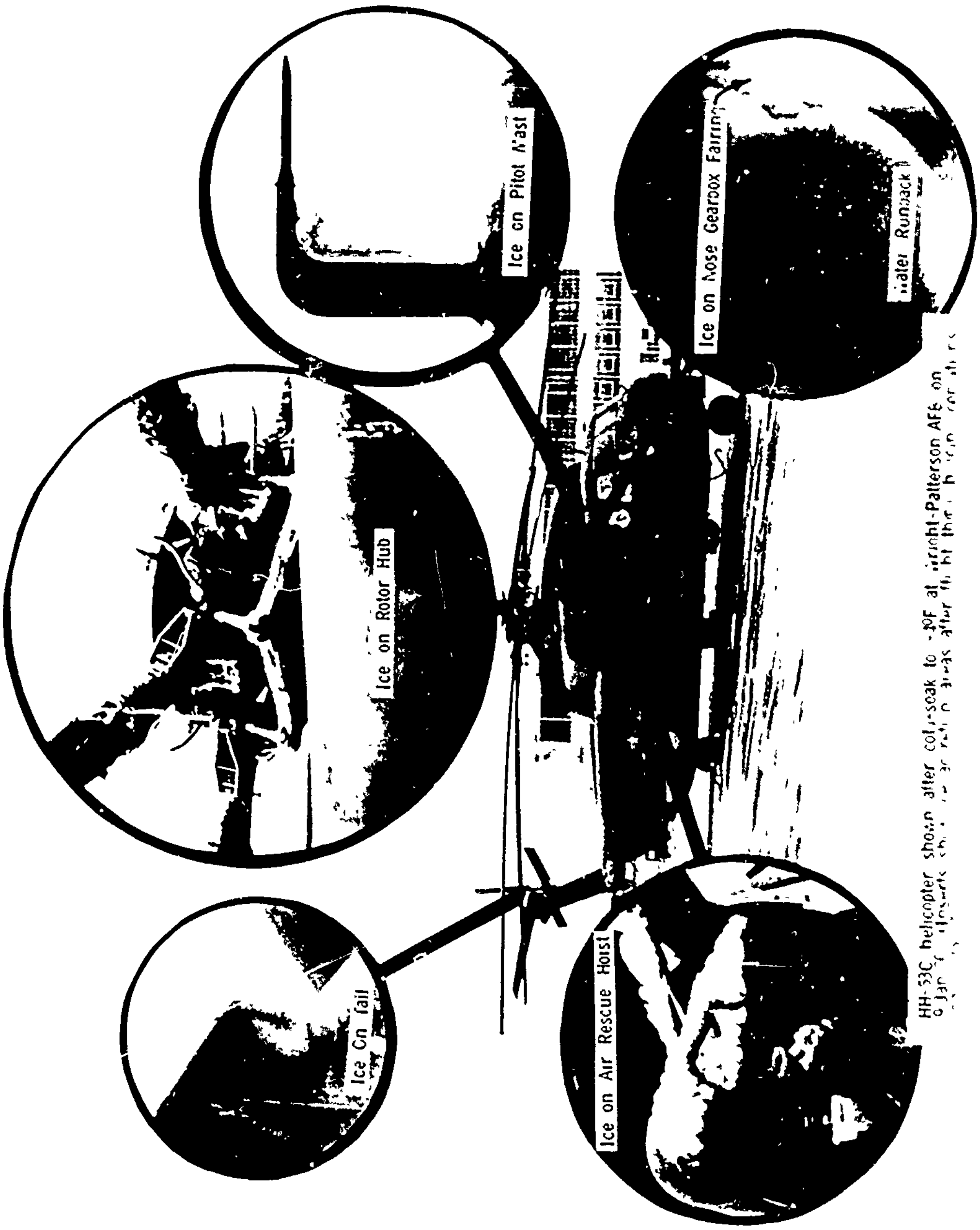


Figure 7. Composite of Helicopter Icing

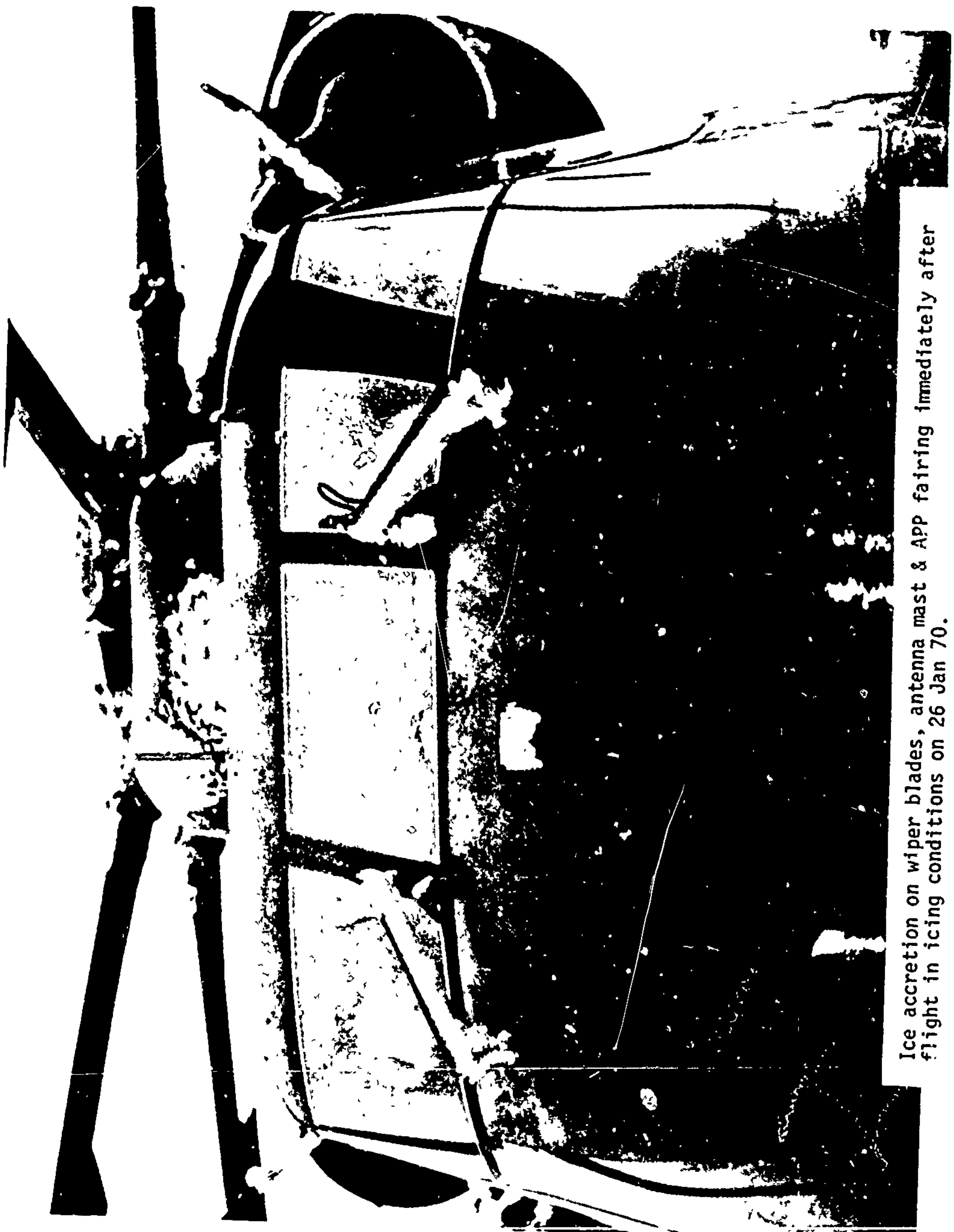


Figure 8. Ice Accretion on Front of Helicopter

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11 SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
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13 ABSTRACT Instrumentation and thermocouples were installed to record basic flight parameters and to pick up temperature variations in HH-53C helicopter for evaluation during all phases of operation in actual and simulated adverse weather. Eighteen missions were flown for a total flight time of 31 hours and 15 minutes. The HH-53C gave a safe performance in both running takeoff and hovering takeoff; and cruising flight in instrument conditions presented no undue hardships. This helicopter provides a large amount of IFR instrumentation and several approach airspeeds for instrument landing, and characteristically displayed satisfactory handling and control in instrument flight, with reasonable safety and recovery capability in case of subsystem failure. Holding patterns and turns were executed according to procedures outlined in AFM 51-37. Tentative procedures and comments by pilots were used in accomplishing instrument and missed approaches. Practice touchdowns up to 60 knots were made. Takeoffs and landings in snow helped in establishing procedures for meeting "whiteouts" experienced in powdery snow. Landing sequences were designed to assist pilots in poor visibility. Uncleared runways and extreme weather conditions during the winter at WPAFB provided ideal testing conditions of ground handling and taxiing on snow and ice.

Detailed summaries of highly successful flights in natural icing conditions are described. Although an increase in overall vibration was noticed as ice built up on the control surfaces, once the vibrations reached a mild intensity, the ice on the control surfaces appeared to shed, causing the vibration to subside. In light-to-moderate turbulence during flights at low altitude

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Helicopter						
Adverse Weather						
Aircraft Icing						
Rotor Icing						
Jet Engine Icing						
Whiteout						

no unusual problems were experienced. In addition to flight and ground handling evaluations, instrument panel, service accessories, lighting systems, heating and ventilating systems, etc. were continuously monitored. Recommendations for improvements or modifications are proposed along with new or revised procedures for operation to be included in the All-Weather Section of the Flight Manual T.O. 1H-53(H)B-1.